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(6) **Error in the Use of the M1 Gunner's Quadrant.**

(10) Charles A. Bancroft

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| T. R. Vallance | Leniel E. McDonald |
| Director of | Lt Col, Infantry |
| Research | Chief |

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## BRIEF

This study is an attempt to determine how much error the operator of an M1 gunner's quadrant makes (1) in measuring the elevation of a gun tube, (2) in laying the gun in elevation, and (3) in reading the scale of the quadrant.

The two groups of subjects used were six expert gunners from Board Nr 2, CONARC and twenty tank commanders from the Armor Replacement Training Center, Fort Knox. The tanks used were ten M48 phase IV tanks, nine having the gun tubes fixed at different positions, and the tenth having the gun tube free for adjustment of elevation. Each subject read a quadrant scale setting and measured the gun elevation in each of the first nine tanks. In the tenth tank each subject laid the gun tube ten times at the same elevation using the gunner's quadrant.

A probable error of the nine elevation measurements and a probable error of the ten gun lays were computed for each subject. Then an average PE of elevation measurement was computed for each group of subjects, that is, for the experts and for the tank commanders. ~~(See Table 1.)~~ Likewise, an average PE of re-lay was computed for each group. ~~(See Table 2.)~~ The percentage of scale misreadings for each group was also calculated.

The relation of the results to uses of the M1 gunner's quadrant is discussed under Applications, beginning on page 5.

## PREFACE

Discussions with members of the Combat Vehicles Section of Board Nr 2, CONARC yielded the following information:

1. The M1 gunner's quadrant is used frequently for testing fire control equipment, such as the computor T30, and for measuring the lay of the gun in ammunition dispersion tests.

2. The human error involved in the use of the quadrant has not been accurately ascertained.

3. There is a need to know the amount of error contributed to test measurements by the use of the quadrant.

Upon further investigation it was found 1) that students in Advanced Individual Armor Training at the Armor Replacement Training Center, Fort Knox are taught how to measure gun elevation and how to lay the tank gun with the M1 quadrant and 2) that the quadrant using proficiency of gunners who have completed training is not precisely known.

Because information on the subject is needed, a study was designed for the purpose of determining the amount of error made in using the M1 quadrant for a group of experts and for a group of trainees who have completed ARTC training. The data were collected in April 1955. This report is a summary of the study.

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Error in the Use of the M1 Gunner's Quadrant

## PURPOSE

The purpose of this experiment is to determine how much error the operator of an M1 gunner's quadrant makes 1) in measuring the elevation of a gun tube, 2) in laying a gun tube at a specific elevation, and 3) in reading the scale of the quadrant.

## PROCEDURE

Two groups of subjects were used in the study, six expert gunners from Board Nr 2, CONARC and twenty tank commanders from the Armor Replacement Training Center, Fort Knox. The experts had been using the quadrant frequently for a considerable time. The tank commanders had received only Armor Branch Individual Training in using the quadrant. Ten tanks M48, Phase IV, were used, nine having gun tubes fixed at different elevations, and the tenth having the gun tube free for adjustment of elevation.

Each subject, when he entered the first tank, was given a gunner's quadrant M1 with the scale set at a specific value. He read the scale setting to the nearest .1 mil. Next he measured the elevation of the gun by placing the quadrant on the breech, leveling the bubble, and reading the resulting scale setting. The tester also read this scale setting in order to separate any scale misreading of the subject from his manipulation of the quadrant.

The subject then moved to the second tank, read the quadrant scale at a second setting, and measured the elevation of the gun tube at a second position. This procedure was repeated until he had read the quadrant at nine specific scale settings and measured nine specific gun elevations. The tester corrected any grossly incorrect handling of the quadrant by the subject.

In the tenth tank each subject was given a quadrant and asked to lay the gun manually at a specific elevation. He re-layed nine times at the same elevation. After each lay the quadrant was removed from the breech, its scale setting returned to zero, and the elevation of the gun thrown off. Any subject who was not proficient in the use of the quadrant received coaching from the tester before beginning the task. In this way gross errors of manipulation and mistakes in quadrant scale reading were reduced. The elevation of the gun tube was measured after each lay by means of a traveling microscope, in essentially the same way it was used by Thune.[1]

Both turret hatches were kept open during the test so that lighting inside the turret would be similar to that which prevails during field tests. Weather conditions on test days varied from clear and sunny to sunny with moving clouds.

## ANALYSIS AND RESULTS

A. Elevation Measurement:

A probable error in mils was computed for the nine elevation measurements made by each subject. The readings used for this computation were those which the tester made after each reading by the subject. The PE thus reflects error made by the subject in placing the quadrant and in leveling the bubble, but not in reading the scale.

If during a measurement, the teeth of the coarse scale of the

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[1]L. E. Thune and A. J. Eckles, III, Consistency in Re-laying as a Factor in Tank Gunnery, draft Technical Report (Fort Knox; Human Research Unit Nr 1, October 1954), pp. 1-2 and Figure 1.

quadrant were not meshed, that particular reading was discarded. (This type of error occurred not at all for experts and only three times for the tank commanders.)

Next, average PE's were computed for the six experts combined and for the twenty tank commanders (TC's) combined. These averages are shown in Table 1, along with the lowest individual PE and the highest individual PE for each group.

Table 1

Average, Lowest, and Highest PE of Elevation Measurement for The Expert and the TC Groups

| Expert Group | PE in mils | TC Group | PE in mils |
|---|---|---|---|
| Average PE | .0573 | Average PE | .2086 |
| Lowest PE | .0280 | Lowest PE | .0413 |
| Highest PE | .1020 | Highest PE | .6158 |

B. Re-Lay of Elevation:

A PE in mils was computed for the ten lays in elevation made by each subject. Next, average PE's were computed for the expert group and for the TC group. These averages are shown in Table 2, along with the lowest individual PE and the highest individual PE for each group.

Table 2

Average, Lowest, and Highest PE of Re-lay in Elevation for The Expert and the TC Groups

| Expert Group | PE in mils | TC Group | PE in mils |
|---|---|---|---|
| Average PE | .0569 | Average PE | .0946 |
| Lowest PE | .0287 | Lowest PE | .0395 |
| Highest PE | .0841 | Highest PE | .1948 |

C. Statistical Tests:

Table 3 shows the results of *t* tests between: 1) average PE for tank commanders and experts for elevation measurements and re-lay tasks; 2) average PE of elevation measurements and re-lay tasks of tank commanders. A line connecting two values in the table indicates a difference which is significant. Data for the computation of *t* values are supplied in Appendix A.

Table 3

Average PE of Experts and Average PE of Tank Commanders for Measurement of Elevation and for Re-lay in Elevation

| | Measurement of Elevation PE in mils | Re-lay in Elevation PE in mils |
|---|---|---|
| Expert group | .0573 ** | .0569 ** |
| TC group | .2086 | .0946 |

** Significant at .01 level

D. Scale Reading:

Indications of any misreading of the quadrant scales were obtained from two sources. First, the subjects were required to read a fixed scale setting when they entered a tank. Second, they were required to read their quadrant settings from measurement of elevation. About the same number of misreadings were made on each task. The two tasks required of each subject a total of 18 scale readings.

The proficiency of scale reading for the TC group varied from all 18 readings correct to no readings correct.[2] The total number of misreadings was 194 out of 360 readings, an average of 54 per cent incorrect.

In the expert group three of the subjects made no scale reading errors. Out of 42 readings, the other three experts made 13 misreadings, an average of 31 per cent incorrect.

[2] A correct reading had to be accurate to the nearest .1 mil.

## DISCUSSION

The obvious explanation for the difference between expert and TC groups for both tasks is the greater experience and ability of the expert group. The experts had used the quadrant frequently in firing tests, whereas the TC's had studied the use of the quadrant only during Advanced Individual Armor Training, and had very little practical experience.

The difference between measurement of elevation and re-laying for the TC group is not so readily explained. Since there is no corresponding difference for the expert group, it may have been due to 1) increase in the quadrant-using proficiency of the TC's during the test or 2) greater control by the tester on the re-lay task. On the measurement task the tester allowed the subject greater freedom to make errors in handling and placing the quadrant.

It should be noted that the errors of measurement dealt with in this experiment are variable errors and not constant errors. In order to evaluate constant error, it would have been necessary to use an instrument which measures absolute elevation of the gun tube much more accurately than the gunner's quadrant measures it. No such instrument was available; but whenever the quadrant is used to measure difference in elevation instead of absolute angle of elevation, constant error does not affect the measurement.

## POSSIBLE APPLICATION OF THE RESULTS

One current use of the M1 gunner's quadrant is to measure the superelevation of the tank gun during tests of the primary direct sighting and fire control equipment. The PE of measurement, .057 mils at 1500 yards, made by the experts in using the quadrant, is appreciable compared to the accuracy required of the sighting and fire control system.[3] The limits of tolerance for the system are ±0.3 mils at 1500 yards and ±0.7 mils at 4000 yards. At 1500 yards the quadrant readings of experts might be expected to fall within the tolerance limits. But system error in excess of ±0.15 mils might combine with quadrant-using error, and the sum might be recorded as falling outside the ±0.3 tolerance limits; and for this reason the tank might be deadlined. It thus appears that the gunner's quadrant, even in the hands of experts, is not acceptable for the testing and adjusting of sighting and fire control instruments as indicated in TM 9-7012.

Several devices which are commonly used to lay the tank gun in elevation are the telescope T156E, the periscope M20, and boresighting with binoculars M17A1. Data on the PE of re-lay using these devices have been gathered by Thume.[4] Table 4 gives the average PE values for each device.[5] As the table shows, variable gun laying error is smaller

Table 4

PE of Re-Lay in Elevation Using Telescope, Periscope, and Boresighting with Binoculars

| | PE in Mils |
|---|---|
| Telescope T156E | .022 |
| Periscope M20 | .026 |
| Boresighting with Binoculars M17A1 | .049 |

[3]The Department of the Army, TM 9-7012, 90mm Gun Tank M48 (Washington: U. S. Government Printing Office, August 1954), pp. 490-492.

[4]Op. cit., p. 8 and Table 2.

[5]Thune's subjects were the 15 tank crews from the M48 Troop Test conducted by Board Nr 2, CONARC. These crews were experienced in the use of their equipment and are probably comparable rather to the expert group than to the TC group used for this study.

for the telescope, periscope, and boresighting than for the quadrant.[6]

The procedure used by Board Nr 2 for determining dispersion of ammunition is 1) to lay the gun with the Telescope T156E1 or the Periscope M20, 2) to measure the elevation of the gun with the Gunner's Quadrant M1, 3) to fire a five or six round shot group, laying the gun and measuring its elevation before each round is fired, and 4) to measure the vertical and horizontal dispersion of the rounds from the center of the target. The requirement for ammunition is that vertical and horizontal PE's be no greater than .15 mils. In such a test any variable error in laying the gun will increase the dispersion of the rounds and result in an overestimate of dispersion of the ammunition. On the other hand, variable error in measuring the elevation of the gun will result in an overestimate of error of laying the gun; and if gun laying error is subtracted from dispersion of the rounds, the result will be an underestimate of dispersion of the ammunition. In either case, if the variable error is small compared to the dispersion of the rounds, the measurement of dispersion of ammunition will be sufficiently accurate.

Approximate percentages of variable error encountered in ammunition dispersion tests are as follows:

1. The overestimate of ammunition dispersion when laying with Telescope T156E1 is approximately 15 per cent.

2. The overestimate of ammunition dispersion when laying with Periscope M20 is approximately 17 per cent.

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[6]Gun laying error is here assumed to be equivalent to dispersion error (PE) of re-lay. The amount of variable error a gunner makes on the number of initial lays will be the same as that he makes in a series of re-lays; therefore, his expected error on a single initial lay is given by his re-lay dispersion.

3. The underestimate when measuring elevation with the M1 gunner's quadrant (only when this measurement of elevation is used as an estimate of gun laying error and is subtracted from dispersion of the rounds) is approximately 38 per cent.[7]

Another use of M1 gunner's quadrant is to adjust the micrometer scale of Elevation Quadrant M13. The smallest division on the micrometer scale is 1 mil. The average PE of M1 quadrant settings for the TC group was .21, or 21 per cent of 1 mil. The average PE of quadrant settings for the expert group was .06 or 6 per cent of 1 mil. The gunner's quadrant, then, seems adequate for adjusting the scale of the elevation quadrant when it is used by experts; but its accuracy for the task is questionable when it is used by men with less experience.

A new gunner's quadrant M1A1 is now being issued to Armor units. It has a scale which is designed for easier reading by inexperienced operators; thus there should be fewer scale reading errors. But since major scale reading errors were removed in the present analysis, it would be advisable to determine operator error for the new instrument before it is used for purposes requiring less than .05 mil PE dispersion error.

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[7]The per cent values were computed by dividing the PE's listed in Tables 1 and 4 by .15 mils, the maximum PE for acceptable ammunition.

## APPENDIX A: DATA FOR $t$ TESTS REPORTED IN TABLE 3

1. Difference between average PE of the expert group and average PE of the TC group for measurement of elevation.

| | Expert | TC | | |
|---|---|---|---|---|
| N | 6 | 20 | $\sigma_{diff\ \phi}$ | = .0492 |
| $M_{\sigma\phi}$ | .0850 | .3093 | $t$ | = 4.568 |
| $\sigma_{m\sigma\phi}$ | .0154 | .0467 | df | = 24 |
| $M_{PE\phi}$ | .0573 | .2086 | p | < .001 |

2. Difference between average PE of the expert group and average PE of the TC group for re-lay.

| | Expert | TC | | |
|---|---|---|---|---|
| N | 6 | 20 | $\sigma_{diff\ \phi}$ | = .0367 |
| $M_{\sigma\phi}$ | .0843 | .1402 | $t$ | = 3.07 |
| $\sigma_{m\sigma\phi}$ | .0118 | .0138 | df | = 24 |
| $M_{PE}$ | .0569 | .0946 | p | < .01 |

3. Difference between average PE of the TC group for measurement of elevation and average PE of the TC group for re-lay.

| | Measurement | Re-lay | | |
|---|---|---|---|---|
| N | 20 | 20 | $\sigma_{diff\ \phi}$ | = .0487 |
| $M_{\sigma\phi}$ | .3093 | .1402 | $t$ | = 3.47 |
| $\sigma_{m\sigma\phi}$ | .0467 | .0138 | df | = 38 |
| $M_{PE}$ | .2086 | .0946 | p | < .01 |